

# DUAL COIL ELECTROMAGNET USING RECTILINEAR CROSS-SECTION CORE ELEMENTS WITH ENLARGED HEADS IN A TATTOO APPARATUS

INVENTOR: TODD EVANS

## BACKGROUND OF THE INVENTION

Dual coil electromagnets are used in tattoo machines and are well known in the art. In particular, the dual coil machines operating on a direct current power supply follow the patents of Wagner, U. S. Patent Number 768,413 and Waters, US Patent Number 1,724,812. Both of these machines teach dual coils that are excited by a direct current power supply. This electrical excitation produces a magnetic field that attracts a spring-biased, moving armature bar toward the coils. The motion of the armature bar opens a switch in the electrical circuit causing the current and the magnetic field to decay, thereby allowing the bias spring to return the armature bar to its original position. This closes the switch which completes the circuit again and the process repeats itself. This causes a vibration of the armature bar. This motion is coupled to the tattoo needle, causing it to vibrate axially. The needle can then be used to penetrate the skin and deposit ink, as is well known in the art. The end of each coil opposite the moving armature bar is attached to a connecting bar that is usually also a structural element.

## DESCRIPTION OF THE DRAWINGS

Figure 1 shows a side elevation of the invention.

Figure 2 shows a coil with a rectilinear core.

Figure 3 shows the opposite end of a coil with a rectilinear core.

## DESCRIPTION OF THE INVENTION

As shown in Figure 1, the invention uses two coils 1 placed side-by-side and attached by means of threaded fasteners 3 to a connecting bar 2 that is part of a frame that is a supporting structural element. The connecting bar 2 is made of a magnetic material such as iron or steel and is rectilinear in cross-section. An armature bar 4 is supported by a flat bias spring 5 so that it is suspended over the ends of the cores 13 of the coils 1. The flat bias spring is attached to the frame 14. The armature bar 4 is of rectilinear cross section and is made of a magnetic material such as iron or steel. An air gap exists between the ends of the

cores 13 and the armature bar 4. In the first position, shown in Figure 1, the coils are not energized. The frame 14 supports an upper electrical contact 8 that is axially adjustable and that is electrically insulated. The upper electrical contact 8 is connected to an electrical power supply 12 by an electrical wire 9. A lower electrical contact 7 is attached to the armature bar 4 and is electrically insulated from it. The lower contact 7 is connected to an electrical wire 10 that is connected to the electrical windings of the coils. The return wire 11 from the coils 1 is connected to an electrical switch 15 that is connected to the other pole of the power supply 12. This circuitry is well known in the art. When the switch 15 is closed, current flows through the closed contacts 7 and 8 and through the coils 1, generating an axial magnetic field in the core 13 of each coil 1. The coils are wound and electrically connected such that the direction of the magnetic fields in each coil are in opposite directions. This causes a magnetic flux path from the core of one coil, through the armature bar 4 (in the portion between the core ends), axially through the core of the second coil, through the connector bar 2 (in the portion between the core ends), and axially back through the coil where it started. This continuous magnetic flux path causes the armature bar 4 to be attracted to the coil cores 13 and to move downward as shown in Figure 1. This motion also moves the lower contact 7 downward which opens the electrical circuit causing the current and magnetic field to decay. The bias spring 5 overcomes the decaying magnetic attraction and returns the armature bar 4 to its first position. The lower contact 7 contacts the upper contact 8 and current flows again, recreating the current and magnetic attraction and the motion. The resulting motion is the vibration of the armature bar 4. Coupled to the armature bar 4 is the tattoo needle 6. The motion of the armature bar 4 generates an axial vibration of the tattoo needle 6 that may be used to penetrate the skin and deposit colored ink.

As shown in Figure 2, the core 13 of each coil 1 has a rectilinear cross-section, perpendicular to the axis of the core. Each edge of the cross-section is substantially at right angles to the adjacent sides, and the cross-section has four sides. The lengths of the opposite sides are equal, but the adjacent sides are not necessarily equal. The end of the core closest to the armature bar 4 is designated as the head end. This head end has an enlarged cross-section or in other words, an enlarged head 19. The core is made from a magnetic material, usually iron or steel, and, having a rectilinear cross-section, therefore, producing a core that is a solid parallelepiped. The outer surface of the core 1 is wound with magnet wire 16. The edges of the core 13 can be radiused or chamfered so that the magnet wire 16 is not bent sharply as it goes over the

edges. As shown in Figure 3, a tapped hole 17 is located in the end of the core away from the armature to accept the fastener 3 that attaches the core 13 to the connector bar 2.

As the cores 13 are assembled to the connecting bar 2, it is preferred that an edge of the core cross-section is aligned to be parallel with the edge of the connecting bar 2. It is preferred that the length of the core cross-section aligned perpendicular to the long axis of the connecting bar be equal to the width of the connecting bar. Each core may incorporate features to facilitate the alignment, such as pins or ears that fit into matching holes in the connector bar. These features would also act to resist rotation of the core 13 while in service. A pin 18 is shown in Figure 3 that would engage in a mating hole in the connector bar 2 to provide alignment and anti-rotation of the core 13.

Experimentation using the rectilinear core has shown the surprising result that the smoothness of the vibration of the tattooing machine is increased substantially when rectilinear cores are used in place of circular cross-section cores. This is reflected in the sensation felt by the operator during the tattooing operation. This is of substantial importance since the quality of the artistic result is directly related to the smoothness of the vibration sensation felt by the operator. This smoothness is a long sought goal among tattoo artists and was heretofore unavailable. This surprising result could not have been predicted due to the complexity of the interaction of the magnetic parts and the changing magnetic flux over the changing magnetic air gap between the cores 13 and the armature bar 4.

After experiencing this result and in hindsight, it is suggested that the flux density in the air gap between the cores and the armature bar and the magnetic components have to change less and is more stable with the rectilinear cross-section core. This results in less disturbing acceleration in the armature bar during each cycle and minimizes disturbing changes from one cycle to the next. Since the flux density distributes itself to conform to the geometry of the excited cross-section, using similar cross-sections as set forth in this invention promotes fewer disturbances in the flux field as it passes between each core and the moving armature bar.

Further experimentation has shown the surprising result that increasing the cross-sectional area of the end 19 of the core 13 closest to the armature bar 4, otherwise known as the head end, further improves the smoothness and force profile of the vibration. The core 13 with this enlarged head feature 19 is shown

in Figure 4. The enlarged dimensions of one test core were approximately 0.06 inches per side larger than the basic body dimensions of the core, thus forming a step approximately 0.13 inches in axial length. This results in the local increase in the cross-sectional area of the core 13. The enlargement is symmetrical and may be in one or both of the cross-sectional dimensions.

After experiencing this result and in hindsight, it may be that the head enlargement 19 produces an end effect local disturbance in the magnetic flux field that is advantageous as the armature bar 4 approaches the head enlargement 19. A similar result may be expected from a local decrease in the cross-sectional area of the core 13 in the end closest to the armature bar 4. Similarly, increasing one of the cross-sectional dimensions while decreasing the other cross-sectional dimension may have a beneficial effect.

This invention may be extended to dual coil electromagnets in general.

Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from the spirit of or exceeding the scope of the claimed invention. Accordingly, it is to be understood that the drawings and the descriptions herein are offered by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof.